Prioritizing Energy Efficiency Investments in Corporate Campuses: Opportunities and the Role of Policy

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\(^3\) Professor  
\(^4\) Assistant Professor
• Building energy conservation measures (ECMs) do not achieve their full potential.
• Strategies for choosing ECMs contribute to this problem.
• Policy can help mitigate the issue.
For commercial buildings in the US in 2012:

**848 Trillion Btu**: Potential for energy saving (30% savings)

**$72 Billion**: Potential for energy efficiency investments.

<table>
<thead>
<tr>
<th>Economic/Financial Impact</th>
<th>Residential</th>
<th>Commercial</th>
<th>Institutional</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Savings (Trillion Btu)</td>
<td>1,892</td>
<td>848</td>
<td>293</td>
<td>3,033</td>
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<tr>
<td>Total Investment ($ Bn)</td>
<td>182</td>
<td>72</td>
<td>25</td>
<td>279</td>
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</tbody>
</table>

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<tr>
<th>Social Impact</th>
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<tr>
<td>Cumulative Job Years Created (# FTEs over course of investment program, '000s)</td>
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<th>Environmental Impact</th>
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<tr>
<td>Greenhouse Gas Emission Reduction (million metric tons of CO₂ mitigated per year)</td>
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</table>

Actual savings are far lower than the potential.

- Investment in commercial buildings energy efficiency: $7.7B
- Energy per square foot reduction achieved: 1.4%
- On average, retrofit projects under-achieve predicted savings by a factor of more than 2.

ACEEE (2008) 2004 data
Deutsche Bank & Living Cities (2011); Shapiro (2011)
Strategies for choosing ECMs

- buildings
- retrofits
Case study: Strategies for choosing ECMs


Building Elec. Cons., Gas Cons., HDD, CDD

Name: 9
ID: 8
Type: Developer Building
System Type: A
Office Space: 107250.6
Lab Space: 7689
Cafe Space: 15670.7
Warehouse: 0
Tot. Fl. Area: 130610.3

Building Elec. Cons., Gas Cons., Headcount, No. Comp.
(1/3) Large, energy-intense buildings are disproportionately chosen for retrofit.
Large, energy-intense buildings are disproportionately chosen for retrofit.

• All else equal, this is a good strategy.
  - When installing a new chiller system that is 20% more efficient, better to start from high-intensity buildings.

• High-potential kWh savings in small & medium buildings are ignored for small-scale retrofits in largest buildings.
(2/3) Majority of projects are focused on Lighting, Control Sequence Revision, and Setpoint Change.
(3/3) Passive strategy for retrofits: “if it’s not broken, don’t fix it”.

Energy Consumption

Energy Savings Compared to Baseline
Barriers to optimal decision making for EE projects

1. Unreliable information on potential savings.

2. Lack of actionable benchmarking metrics.

3. Split incentives (both externally and internally).
(1/3) Energy audits are unreliable and biased.

- 53% over-estimate savings potential.
- 60% did not thoroughly review the building.
- 60% under-estimated installed costs by a factor of 2+.
- 80% did not consider all potential improvements.
- Commercial building audits are focused on HVAC and lighting.
- And widely ignore insulation and infiltration.

Shapiro (2011) based on a study of 300 energy audits
Ratings are used for visibility purposes instead of decision support.

"Going after Energy Star is kind of a public tool. We've used LEED a couple of times now to basically demonstrate to people that we are serious and we're taking into account sustainable design elements. “

Commercial Real Estate Executive

Peterman et al. (2012)
(3/3) Split incentives (external)

- Tenant v. owner
- Lack of a verified business case

"We can't get the company to pull the trigger on putting in LED parking lot lights because they're not sure [...] how our customers are going to feel about those types of parking lights."

- Retail Executive

Peterman et al. (2012)
(3/3) Split incentives (internal)

**Executives**
- Company image
- Employee comfort

**Facility managers**
- Run the facilities smoothly

**Energy Managers**
- Reduce carbon
- Reduce energy $
Policy role

- Technical guidance
  - DOE Buildings Performance Database

- Codes & standards
  - ASHRAE’s *Procedures for Commercial Building Energy Audits*

- Align incentives
  - Codes, standards, and mandates to bring fundamental ECMs into day-to-day decision making across all organizational levels (NYC, SF mandates for RCx and audit).
  - Building performance transparency to bring efficiency to senior management’s attention.
Aligning incentives across all levels of organizations

“We are now investing in energy efficiency because our customers and shareholders want it.”

Commercial bank executive
Peer groups and network effect

“I can’t wait for your analysis to be done so we can sit down and you guys tell me how we are doing compared to [...].”
Huge potential for energy efficiency – largely untapped

• With existing technologies, it is economically possible to reduce commercial buildings energy consumption by 30%.

• With emerging technologies, by 2020, it will be economically possible to reduce commercial buildings energy consumption by 80%.
Case study

- Interviewing energy managers and facility managers
- Strategies for energy conservation measures
RCx, HVAC Equipment Retrofit, and Electrical Retrofits show the highest savings potential.
Energy managers …

- Energy intensity (kWh/sqft) and ROI are useful, but should not be the only metrics to select projects.
  - Total kWh savings from all buildings.
  - Include non-energy savings.

- Invest savings from shorter payback projects into a capital planning budget to finance additional improvement projects.

- RCx has great potential but is under-utilized
  - Time and resource intensive if done manually.
  - Utilize continuous commissioning systems and fault detection systems.
Significant amount of energy is lost every year due to factors controllable by better energy management

- **400%** variation in energy use intensity of commercial buildings that is not explained by age, technology, hours, size, climate.

- **$193.9 billion** of annual energy costs in the U.S. are lost as a result.

EPA (2012)
Many EE programs underachieve

- Ex ante models predictions for energy savings:
  25% to 50%

- Ex post analyses verified savings:
  10% to 40%*

Deutsche Bank & Living Cities (2011); Shapiro (2011)
Other retrofits suggest even more savings

Westphalen & Koszialinksy (2001)
Why EE projects under-achieve?

• Design

• Implementation

• Inaccurate estimation of savings potential

• Sub-optimal choice of energy efficiency projects
  – Choice of buildings
  – Choice of projects
Majority of projects are focused on HVAC Equipment Retrofit, Lighting, and RCx.

Volume of Energy Efficiency Projects

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume by Expected Saving (KWh/Yr)</td>
<td>6,000,000</td>
<td>4,000,000</td>
<td>2,000,000</td>
<td>0</td>
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</tbody>
</table>

Legend:
- Behavior Change
- Control Sequence Revision
- Electrical Other
- HVAC - Equipment Retrofit
- HVAC - Setpoint Change
- HVAC - VFD Retrofit
- Lighting
- RCx

VFD: Variable Fan Drive
RCx: Retro-Commissioning
Cumulative expected savings from ECMs
Energy Star score does not correlate with energy savings potential.

Source: Retroficiency’s virtual audit of 500 commercial buildings in the US (2013)
Passive strategy for retrofits: “if it’s not broken, don’t fix it”.

Energy Consumption

Energy Savings Compared to Baseline
Passive strategy for retrofits: “if it’s not broken, don’t fix it”.

![Energy Consumption Chart]

- **Energy Consumption**
  - Baseline vs. Measured

![Energy Savings Compared to Baseline Chart]

- **Energy Savings Compared to Baseline**
  - Cumulative vs. Monthly
Passive strategy for retrofits: “if it’s not broken, don’t fix it”.

[Energy Consumption Graph]

[Energy Savings Compared to Baseline Graph]
Prioritization tool for energy efficiency investment
Improve the standards for energy audits

- ASHRAE’s *Procedures for Commercial Building Energy Audits*.

- Federal, state, and utility-specific requirements for audits are uneven and partially cover the building stock.

- Better standards, templates, and training are needed.
Aligning organizational incentives (externally and internally)

### Commercial Buildings Codes:

- **Most efficient:** Meets or exceeds American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1 – 2007 or equivalent
- **Meets or exceeds ASHRAE Standard 90.1 – 2004 or equivalent**
- **Meets or exceeds ASHRAE Standard 90.1 – 1999**
- **No statewide code or precedes ASHRAE Standard 90.1-1999**
- **State has adopted a new code to be effective at a later date**

### Residential Building Codes:

- **More efficient:** Meets or exceeds 2009 IECC or equivalent
- **Meets or exceeds 2006 IECC or equivalent**
- **Meets or exceeds 1998–2003 IECC or equivalent**
- **Least efficient:** no statewide code or precedes 1998 IECC

As of July 20, 2010.

Numbers in the table indicate the number of policies in each category.

* Combined EERS/RES
Sources: DSIRE, OCEAN, ACEEE

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### Table:

<table>
<thead>
<tr>
<th>State</th>
<th>Personal Tax Incentives</th>
<th>Corporate Tax Incentives</th>
<th>Sales Tax Incentives</th>
<th>Property Tax Incentives</th>
<th>Rebates</th>
<th>Grants</th>
<th>Loans</th>
<th>Bonds</th>
<th>Green Building</th>
<th>Rules &amp; Regulations</th>
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**Legend:**
- **1** = 1 policy
- **X** = 1 policy
- **++** = 2 policies
- **+++** = 3 or more policies

**State Energy Efficiency | October 2010**
### Commercial Buildings Codes:
- Most efficient: Meets or exceeds ASHRAE Standard 90.1 – 2007 or equivalent
- Meets or exceeds ASHRAE Standard 90.1 – 2004 or equivalent
- Meets or exceeds ASHRAE Standard 90.1 – 1999
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### Residential Building Codes:
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### Incentives

<table>
<thead>
<tr>
<th>Region</th>
<th>Arizona</th>
<th>Colorado</th>
<th>Idaho</th>
<th>Montana</th>
<th>Nevada</th>
<th>New Mexico</th>
<th>Oregon</th>
<th>Utah</th>
<th>Washington</th>
<th>Wyoming</th>
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### Rules & Regulations

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As of July 20, 2010.

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As of July 20, 2010.
Sources: DSIRE, OCEAN, ACEEE

<table>
<thead>
<tr>
<th>Region</th>
<th>Delaware</th>
<th>DC</th>
<th>Illinois</th>
<th>Indiana</th>
<th>Maryland</th>
<th>New Jersey</th>
<th>Ohio</th>
<th>Pennsylvania</th>
<th>Virginia</th>
<th>New England &amp; New York</th>
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| **Rules & Regulations** |          |    |          |         |          |            |      |              |          |                        |
| Equipment Standards | 1        |    |          |         |          |            |      |              |          |                        |
| Energy Standards   |          |    |          |         |          |            |      |              |          |                        |
| Public Buildings   |          |    |          |         |          |            |      |              |          |                        |
| Commercial Building Codes |          |    |          |         |          |            |      |              |          |                        |
| Residential Building Codes |          |    |          |         |          |            |      |              |          |                        |
| Public Benefits   |          |    |          |         |          |            |      |              |          |                        |
| Energy Efficient Resource Standard (EERS) |          |    |          |         |          |            |      |              |          |                        |
| Number of Policies | 8        |    |          |         |          |            |      |              |          |                        |

| Number of Policies | 6        |    |          |         |          |            |      |              |          |                        |

State Energy Efficiency | October 2010

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Encouraging more fundamental retrofits

- Puget Sound Energy Commercial Custom Grant Program
  - Funds up to 70% of most retrofits, up to 50% of lighting retrofits
- RCx and audit mandates
  - New York City “Greener, Greater Buildings Plan"
  - San Francisco “Existing Commercial Buildings Energy Performance Ordinance”
Peer groups and network effect

• economic incentives
• certifications;
• alliances and partnerships;
• internal company programs
Adobe’s Net-Net

Multi-Building Retrofit (PEA)

Offices, Data Center -- 620,000 SF -- 4 Buildings

ENERGY CONSERVATION MEASURES (ECM)  Less Than 4 Years

Analysis: Maintenance, Timing, Life Cycle, Installation Costs, Savings, Future Use

<table>
<thead>
<tr>
<th>ECM</th>
<th>Electric Savings (kWh)</th>
<th>Demand Savings</th>
<th>Annual Savings</th>
<th>Est. Cost</th>
<th>Rebates</th>
<th>Simple Payback</th>
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<tbody>
<tr>
<td>1) Lighting as Needed Lighting Controls</td>
<td>74,300</td>
<td></td>
<td>$7,200</td>
<td>$25,500</td>
<td></td>
<td>3.53 yrs</td>
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<tr>
<td>2) Plumbing System Water and sewer</td>
<td>153,500</td>
<td>$39,400</td>
<td>$143,900</td>
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<td>3.65 yrs</td>
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<td>$11,700</td>
<td>$23,800</td>
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<td>2.04 yrs</td>
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<tr>
<td>3) Chiller Optimization Controls</td>
<td>125,900</td>
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<td>$11,700</td>
<td>$23,800</td>
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<td>2.04 yrs</td>
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<tr>
<td>4) Energy Management Controls System</td>
<td>1,400,000</td>
<td>$131,100</td>
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<td>0.93 yrs</td>
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<td>EMCS-new-only big equipment-Extend to full bdg—advanced metering—Co2 air intake, space override switches, occ. sensors, meter major loads –tie back to original EMCS</td>
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<td></td>
</tr>
<tr>
<td>5) Permafrast Refrigerant Additive</td>
<td>176,300</td>
<td></td>
<td>$16,400</td>
<td>$59,800</td>
<td></td>
<td>3.65 yrs</td>
</tr>
<tr>
<td>6) Power Factor Correction</td>
<td>120 kW</td>
<td>$8,600</td>
<td>$29,000</td>
<td></td>
<td></td>
<td>3.38 yrs</td>
</tr>
<tr>
<td>Subtotal</td>
<td>1,930,000 kWh</td>
<td>120 kW</td>
<td>$214,000</td>
<td>$403,900</td>
<td></td>
<td>1.88 yrs</td>
</tr>
</tbody>
</table>

Source: Honeywell Building Solutions
## Adobe’s Net-Net

### Multi-Building Retrofit (PEA)

#### ENERGY CONSERVATION MEASURES (ECM)

<table>
<thead>
<tr>
<th>ECM</th>
<th>Electric Savings</th>
<th>Electric Demand Savings</th>
<th>Gas Savings</th>
<th>Annual Savings</th>
<th>Gas Therms</th>
<th>Annual Cost</th>
<th>Rebates</th>
<th>Simple Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>7) Kitchen Dishwasher</td>
<td>16,100 kWh</td>
<td></td>
<td></td>
<td>$1,100</td>
<td>-378</td>
<td>$12,300</td>
<td></td>
<td>11.18 Yrs</td>
</tr>
<tr>
<td>High Efficiency Heater</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8) Kitchen Dom. Hot Water</td>
<td></td>
<td></td>
<td>1,744</td>
<td>$1,900</td>
<td>$58,600</td>
<td>30.84 Yrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensing Boiler</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9) Tower-Free Cooling</td>
<td>358,900 kWh</td>
<td></td>
<td></td>
<td>$33,400</td>
<td>$222,400</td>
<td>6.66 Yrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10) Var. Speed Chilled Water Pumping</td>
<td>101,700 kWh</td>
<td></td>
<td></td>
<td>$9,450</td>
<td>$70,900</td>
<td>7.50 Yrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11) New High Efficiency Chiller</td>
<td>144,900 kWh</td>
<td></td>
<td></td>
<td>$13,500</td>
<td>$371,200</td>
<td>27.53 Yrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12) Thermal Storage System</td>
<td></td>
<td></td>
<td>440 kW</td>
<td>$152,830</td>
<td>$1,275,000*</td>
<td>$435,600</td>
<td>8.34 Yrs</td>
<td></td>
</tr>
</tbody>
</table>

**Sub Total**

- Electric Savings: 621,600 kWh
- Electric Demand Savings: 440kW
- Gas Savings: 1366
- Annual Savings: $212,180
- Annual Cost: $2,010,400
- Rebates: $0
- Simple Payback: 9.47 Yrs

* Includes Rebate  ** This ECM was excluded in final totals

<table>
<thead>
<tr>
<th>Subtotal (Less: 4 Yrs)</th>
<th>Electric Savings</th>
<th>Electric Demand Savings</th>
<th>Gas Savings</th>
<th>Annual Savings</th>
<th>Gas Therms</th>
<th>Annual Cost</th>
<th>Rebates</th>
<th>Simple Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,930,000 kWh</td>
<td>120kW</td>
<td></td>
<td></td>
<td>$214,000</td>
<td>$403,900</td>
<td></td>
<td></td>
<td>1.88 Yrs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subtotal (More: 4 yrs)</th>
<th>Electric Savings</th>
<th>Electric Demand Savings</th>
<th>Gas Savings</th>
<th>Annual Savings</th>
<th>Gas Therms</th>
<th>Annual Cost</th>
<th>Rebates</th>
<th>Simple Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>476,700 kWh**</td>
<td>440kW</td>
<td></td>
<td></td>
<td>$198,680**</td>
<td>$1,639,200***</td>
<td>$0</td>
<td></td>
<td>8.25 Yrs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selected Total</th>
<th>Electric Savings</th>
<th>Electric Demand Savings</th>
<th>Gas Savings</th>
<th>Annual Savings</th>
<th>Gas Therms</th>
<th>Annual Cost</th>
<th>Rebates</th>
<th>Simple Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,406,700 kWh</td>
<td>560 kW</td>
<td></td>
<td></td>
<td>$412,680</td>
<td>$2,043,100</td>
<td>$0</td>
<td></td>
<td>4.95 Yrs</td>
</tr>
</tbody>
</table>

**ROI: 20.2%  IRR: 21.1% (10 Year)**

*(Reduce: Elect 10.2%/yr—GHG 4.6Mlbs/yr(13.5%) — EStar 67 to 77, or 330 Cars/yr, 238,000 gal/yr Built 2006)*

*Source: Honeywell Building Solutions*
Summary and recommendations for practitioners

• Investment is limited by availability of funds and the ability to manage multiple projects.

• We are paying too much attention to largest buildings and to “shallow retrofits”.
  – Lighting retrofits high ROI, but low in overall kWh savings.

• RCx works but is under-utilized
  – Time and resource intensive if done manually.
  – Utilize continuous commissioning systems and fault detection systems.

• Invest savings from shorter payback projects into a capital planning budget to finance additional improvement projects.